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Investigation of Ni Metal Induced Lateral Crystallization with a-Si Film Thickness at Very Thin Extent

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1. Introduction

Low temperature polycrystalline-Si (poly-Si) thin-film transistors (TFTs) employing excimer laser annealing (ELA) are widely used in active-matrix organic light emitting diode (AMOLED) displays. However, non-uniformity of the TFT characteristics due to the fluctuation of laser energy results in non-uniformity in OLED current level. On the other hand, metal-induced lateral crystallization (MILC) can grow highly oriented poly-Si film in an uniform way compared with ELA. Besides, the driving current of MILC-TFTs is almost independent of the growth direction of MILC crystals. Therefore, MILC-TFT is a promising candidate for use in current control of AMOLED displays.

In the MILC using Ni as a catalyst, thin slices of $NiSi_2$ whose width is several tens nm move into amorphous-Si (a-Si) leaving crystal Si behind and forming needle-like single crystal Si[1]. So a large amount of Ni or $NiSi_2$ remain in the crystallized film, and result in the increase of cut-off current. In our previous study, we could successfully reduce the cut-off current of MILC-TFTs by thinning Si film to about 50 nm. However, there are few reports concerning MILC with a-Si film thickness less than 50 nm. In this paper, we report new findings on MILC with a-Si film thickness at very thin extent.

2. Experimental

Figure 1 shows schematic illustration of Ni-MILC process. In the experiment, a-Si film was deposited on thermally oxidized Si wafer by using an ultra-high vacuum evaporator. We formed multiple regions on a single substrate, where each region has a different a-Si film thickness from others, by controlling a shutter during deposition. The thickness of a-Si film including very thin region was measured by using spectroscopic ellipsometry. The capping-SiO_2 layer was formed by spin-on-glass (SOG), and an aperture was opened in the capping-SiO_2 film as the Ni-supply area for MILC. Ni film (a few nm thickness) was vacuum evaporated. After a few μm initial growth of Ni-MILC at 600°C, an excess Ni was eliminated by wet etching with a mixture of HCl : H_2O_2 (1 : 1). Ni-MILC was carried out at 600°C in N_2 ambient to investigate the growth characteristic. We observed MILC crystals by using optical microscope and scanning electron microscope (SEM) to investigate the change in MILC crystalline morphology.

3. Results and Discussion

Figure 2 shows Ni-MILC growth characteristics with various film thickness from 5 to 70 nm. The Growth speed was found to be reduced with decreasing the film thickness. Especially, the growth speed reduced remarkably at the film thicknesses between 20 and 10 nm. Furthermore, we confirmed that Ni-MILC growth didn't occur in case of 5 nm-thick a-Si. These results indicate that the migration of $NiSi_2$ precipitates becomes difficult since a-Si film thickness is thinner than the thickness of $NiSi_2$ which can exist stably in a-Si film.

Figure 3(a) shows SEM image of Ni-MILC crystal with a thickness of 60 nm at the growth front after Secco's etching. Figure 3(b) shows optical micrograph of MILC crystal with a thickness of 15 nm. The $NiSi_2$ precipitates are octahedra bounded by eight {111} faces, and the lattice mismatch between $NiSi_2$ and Si is only 0.4%. Therefore, the migration direction of $NiSi_2$ is <111>, and needle-like Si whose growth direction is almost parallel to the substrate surface can survive. As a result, a set of needle-like Si crystals having {110} preferred surface orientation can be formed. And it is known that the needle-like crystallites grow while repeating "turn" or "branch" toward equivalent <111> directions (70.5° and 109.5°)[1] as shown in Fig. 3(a). On the other hand, the angle for "turn" or "branch" of needle-like crystallites was found to be 90° in case of 15 nm-thick a-Si as shown in Fig. 3(b). These results suggest that the crystallographic orientation of Ni-MILC crystal changes as decreasing the film thickness.

From these results, we hypothesized the phenomenon as shown in Fig. 4. Figures 4(a) and 4(b) show stereographic projection for the cubic crystal system (110) and (100). As mentioned above, in the case where the thickness of a-Si film is thicker than 20 nm, $NiSi_2$ slices migrate parallel to the substrate surface. Then the growth direction is <111>, and the surface orientation of MILC crystal is {110} as shown in Fig. 4(c). On the other hand, in the case where the thickness of a-Si film is thinner than 20 nm (about 15 nm), the surface orientation of MILC crystal become {100} because the needle-like crystallites intersect at 90° each other. Taking into account the fact that $NiSi_2$ forms the facet of (111) whose surface free energy is lowest, $NiSi_2$ slices are considered to tilt in a-Si film. Therefore, the growth direction is considered to become <110> as shown in Fig. 4(d).

4. Conclusions

We have investigated the growth characteristics and crystal morphology of Ni-MILC with a-Si film thickness at very thin extent. The growth speed reduced remarkably at the film thicknesses between 20 and 10 nm. Besides, we observed that the needle-like crystallites intersected at 90^o each other in case of 15 nm-thick a-Si film. These experimental results suggest that the crystallographic surface orientation of Ni-MILC crystal changes into {100} and the growth direction changes into <110> as decreasing the film thickness to about 15 nm.

Acknowledgements

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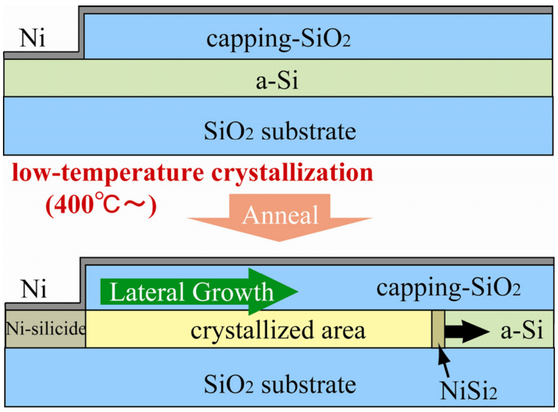

Figure 1 : Schematic illustration of cross-sectional sample structure for the Ni-MILC growth.

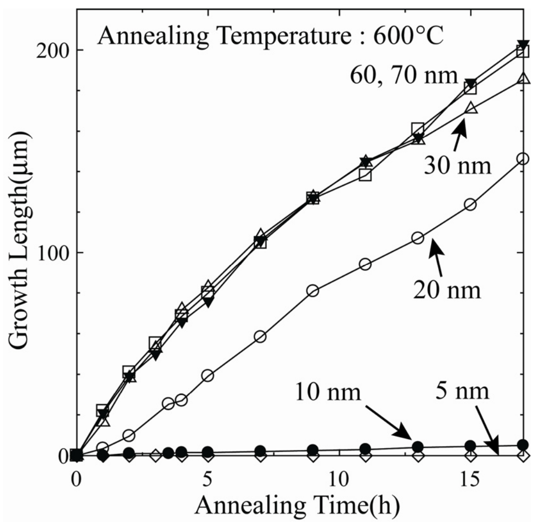

Figure 2 : Ni-MILC growth characteristics with various film thickness from 5 to 70 nm.

Reference

[1] M. Miyasaka, K. Makihira, T. Asano, E. Polychroniadis and J. Stoemenos : Appl. Phys. Lett. **80** (2002) 944.

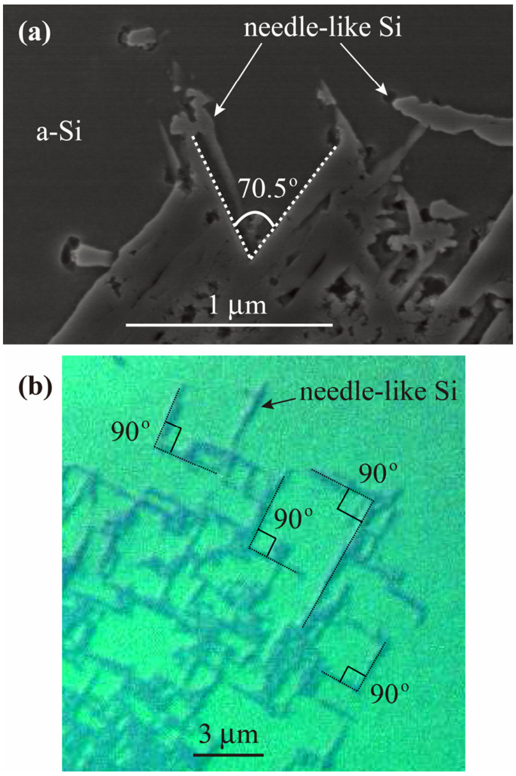

Figure 3 : (a) SEM image of Ni-MILC crystal with a thickness of 60 nm at the growth front, and (b) optical micrograph of Ni-MILC crystal with a thickness of 15 nm.

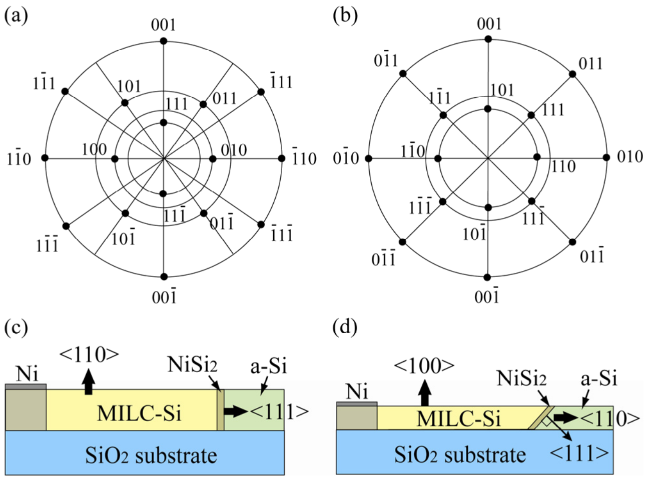

Figure 4 : (a) Stereographic projection for the cubic crystal system (110), and (b) that for the cubic crystal system (100). (c) Growth model for the case where the thickness of a-Si film is thicker than 20 nm, and (c) that for the case where the thickness of a-Si film is thinner than 20 nm (about 15 nm).